THE WEATHER AND CIRCULATION OF JUNE 1951

LeROY H. CLEM

Extended Forecast Section, U. S. Weather Bureau, Washington, D. C.

June 1951 was a month of great contrasts over the United States. Drought in the Southwest and deep South was coupled with record-breaking amounts of rain which set the stage for the most destructive flood in the Nation's history in the central Great Plains. In addition, it was the coldest June on record at several points in Montana and Nebraska and very nearly the coldest for Wyoming, Colorado, and Kansas where the mean monthly temperatures were more than 5° below normal. On certain days, minimum temperatures were below freezing as far south as Denver, Colo., and Goodland, Kans., and appreciable amounts of snow fell in portions of the northern Rocky Mountains, Wyoming, Colorado, and the Dakotas. Conversely, the month was much warmer than normal in the western Gulf States, especially in the Big Bend Country of Texas, where Presidio's 116° F. on the 20th nearly broke the June record. Stations in southeastern New Mexico recorded daily maximum temperatures which equalled the all time high for the month. The normal June temperatures at Dodge City and Presidio are 73° F. and 84° F. respectively, and differ by 11°. This month the difference was 22° F., as Dodge City recorded a 6° below-normal reading of 67° F. while Presidio observed a warm 89° F.

These anomalous temperature fields and the attendant weather were closely associated with some of the more prominent features of the mean circulation over North America and adjacent oceans during June (fig. 1). The most pronounced and probably most significant feature was the unusually strong ridge in the eastern Pacific at all levels of the atmosphere up to at least 40,000 feet. (Charts XI–XV.)[1] Figure 1 shows that the heights in this ridge at 700 mb. were as much as 300 feet above normal, while Chart XI inset indicates that at sea level the pressures departed from the normal in a similar fashion by as much as 9 mb.

Immediately upstream from this ridge a deep trough extended from the Aleutian Low, which was south of its normal position, to the Hawaiian Islands. As might be expected from the large amplitude of this Pacific trough-ridge system, a well defined trough was located downstream, extending from south central Canada through the southwestern United States. Since heights were below normal in this trough as well as throughout northwestern Canada, strong northwesterly and northerly flow relative to normal was observed from the Gulf of Alaska and northwest Canada to Montana, Wyoming, and Colorado. This anomalous flow brought surge after surge of abnormally cold air into the northern Rocky Mountain and Great Plains States [1]. The cold air masses worked their way southward through the trough and then, under the influence of the prevailing circulation, they moved eastward across the central Great Plains. The southern boundary of their invasions was generally in Oklahoma. The flow between the above-normal heights centered in the Gulf of Mexico and the below-normal heights in the trough in the Southwest was more southerly and southwesterly than normal over Texas and Oklahoma. This circulation helped divert the cold air masses toward the east and brought the hot moisture-laden air from the Gulf of Mexico into contact with the cold surges from the north. The recurring interaction of these contrasting streams of air resulted in devastatingly heavy rains in the central Great Plains which, after an especially wet May [2], led to extensive flooding in Kansas, Missouri, and Nebraska.

Rainfall was generally greater than normal throughout most of the region from the Gulf Coast of Texas northward to Montana and Minnesota, excepting North Dakota (Charts III A and B). In the northern part of this above-normal precipitation area, the rain was associated with the mean trough and negative height anomalies. In the south shower activity, occurring in the warm unstable Gulf air, was responsible for much of the rain. The rainfall was especially heavy near the central Texas Gulf coast where, early in the month, a cold front set off such record-breaking downpours as 6.18 inches at San Antonio in 24 hours.

It was in the central part of this region that the main interplay of the two contrasting air masses occurred. This central area, including nearly the entire State of Kansas, received over 200 percent of its normal rainfall amount. Storms ravaged practically all parts of Kansas throughout the month. Records from all sections of the State showed that the average rainfall for Kansas during June was 9.69 inches, nearly 6 inches above the normal and the greatest amount for any one month in the 65 years that records have been maintained. This amount was nearly an inch more than that for the next wettest month, July 1950, and nearly 2 inches more than for the previous wettest June which was in 1908. The appropriately named community of Climax, just east of Wichita, reported 16.5 inches for the greatest monthly total of all, while more than one-

[1] See charts I–XV following p. 132 for analyzed Climatological Data for the month.

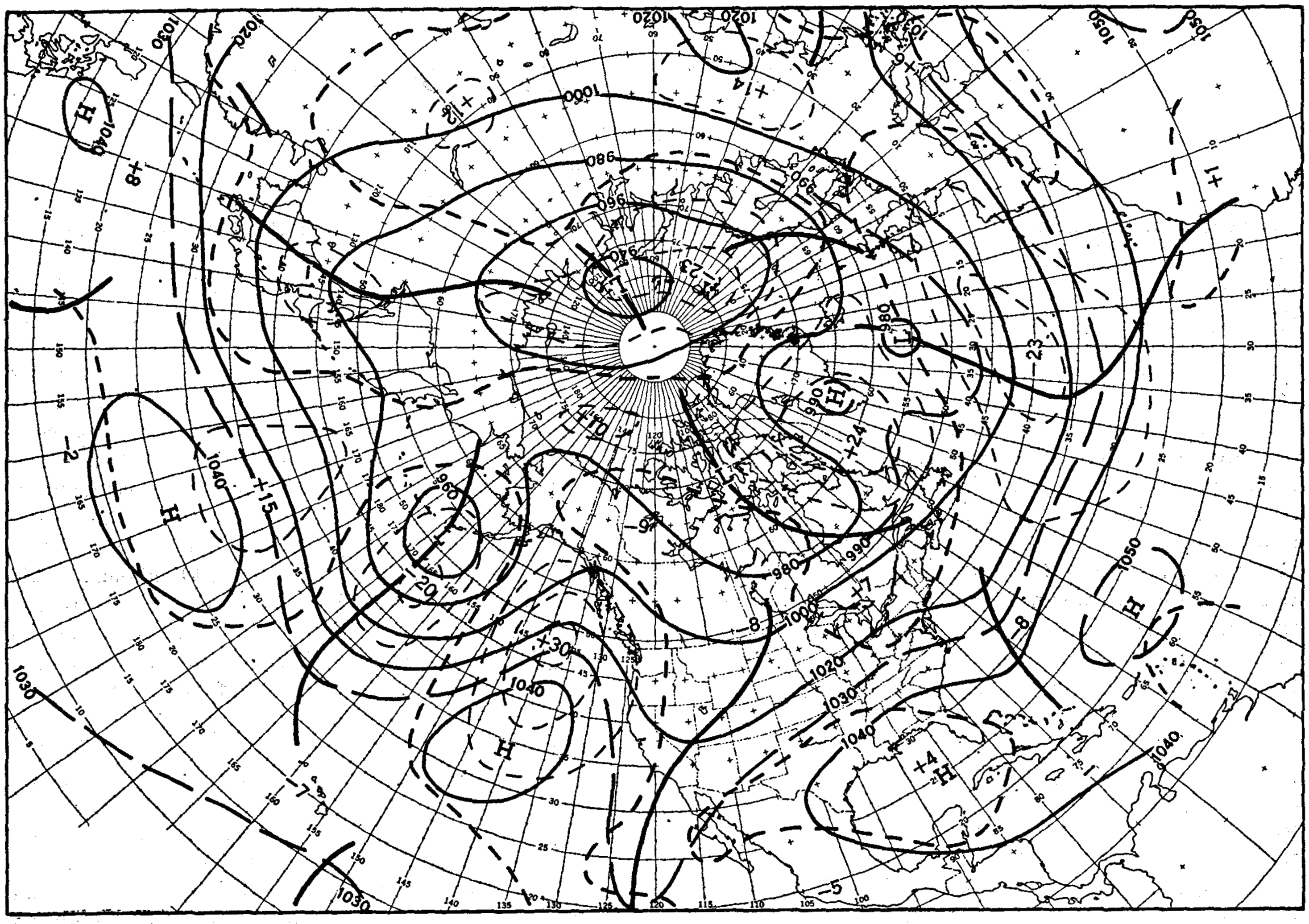


FIGURE 1.—Mean 700-mb. chart for the 30-day period May 28–June 27, 1951. Contours at 200-foot intervals are shown by solid lines, intermediate contours by lines with long dashes, and 700-mb. height departures from normal at 100-foot intervals by lines with short dashes with the zero isopleth heavier. Anomaly centers and contours are labeled in tens of feet. Minimum latitude trough locations are shown by heavy solid lines.

third of the stations reported monthly totals in excess of 10 inches. The nearly-routine weather summary was "severe thunderstorms, frequently accompanied by hail, high winds, and sometimes tornadoes". In addition to excessive rainfall and flood losses, conservative damage estimates from 42 tornadoes, 34 hailstorms, 20 severe windstorms and 34 lightning strikes totalled $26,439,275. One hundred and seventeen injuries were reported, many from such observed conditions as 90 m. p. h. winds driving the hail which occasionally was reported to be golf ball size or larger. Lightning caused two deaths and tornadoes were responsible for six more. Such were the disastrous results when the general circulation oriented itself in such a manner as to bring together two completely opposite streams of air; one, the abnormally cold air from the Gulf of Alaska and northwest Canada which tenaciously clung to the ground like a heavy liquid, and the other, the warm moist stream of air from the Gulf of Mexico which, being lighter, was forced up over the tapered edge of the cold air as the two streams met. Finally, as this warm air cooled beyond the condensation point, rain and energy were released, sometimes with unusual violence.

In contrast to the very wet conditions in the central Great Plains, extreme drought prevailed over nearly all of the Southwest. At Albuquerque, located in the region of prolonged drought, the rainfall during the first 6 months of 1951 was less than 40 percent of the normal. It was so dry toward the latter part of the month that Albuquerque several times reported relative humidities under 10 percent. The record low of 3 percent was observed during the night of June 22. In parts of Arizona and New Mexico more cloud cover than normal (Chart VI–B) was observed. This cloudiness was associated with rather weak activity moving in the general flow east of the mean trough in the Southwest and resulted in temperature departures from normal of −1°. Unfortunately this cloud cover was not effective in bringing the much-needed rainfall to the drought area. In general, scarcely more than a trace of rain was reported for most of the region during the entire month of June. It is interesting to note that the region of drought in the Southwest was under the influence of anticyclonic relative vorticity at 700 mb. (fig. 2). In addition, the trajectory of the air both at sea level and aloft was from a dry source rather than from the Gulf of Mexico.

Another region where the air was warmer and drier than normal was the Far West. The mountains acted as a barrier in keeping the cold air restricted on their eastern side. In the northern portion, warm weather was associated with above-normal heights on the east side of the Pacific ridge. The attendant subsidence resulted in clear skies and increased sunshine (Charts VI and VII). Also the flow relative to normal brought into the area air from over warmed land surfaces rather than directly from over the cold waters off the west coast. During the middle of the month, under the clear skies associated with a warm High over the interior Plateau region, the temperature departure was nearly 10° above normal. The warmer-than-normal air in the southern part of the Far West (Chart I–B) was associated with the well developed thermal trough (Chart XI). The existence of the sea breeze can be seen from the wind roses (Chart XI) along the California coast. The effect of this sea breeze on the temperature anomaly (Chart I inset) and on the percentage of clear skies (Chart VI) is very pronounced along the west coast. These features are characteristic of this type of synoptic situation, especially when the water temperatures are much colder than the land during the day. Most of the rainfall in the central California-Nevada area came early in the month with a storm passage (Chart X), while the rainfall in the interior of Washington came from occasional storms moving down the east side of the Pacific High. In contrast, drought conditions and forest fire hazard prevailed in northern California and western Oregon in connection with above-normal heights and anticyclonic relative vorticity at 700 mb. (fig. 2). Another good indication of the nature of the air in these regions is the anomalous offshore dry flow at sea level (Chart XI inset).

Following the sea level pressure anomaly chart to the eastern half of the Nation, we find a band of minimum values from the flood areas of the Great Plains through the middle Atlantic seaboard and out into the ocean. The path of the heavy precipitation, produced by storm centers moving eastward in the flow aloft, closely agreed with this channel in the sea level pressure and 700-mb. height anomaly charts.

Quite in contrast to these excessive amounts of rain, the Mississippi delta country was fast losing its battle with a prolonged drought of nearly 2 months. By the end of the first week in June, Jackson, Miss., had received only 0.13 inch of rain since the 21st of April [2]. Crop failure there was almost complete. Sources of drinking water were drying in southern Louisiana toward the end of the month. This subnormal rainfall was associated with abnormally high sea level pressures and above-normal heights and anticyclonic vorticity at 700 mb. (figs. 1 and

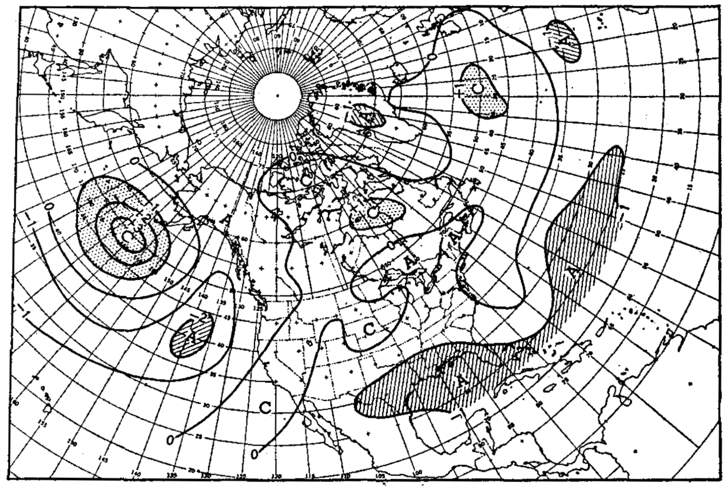


FIGURE 2.—Vertical component of mean relative geostrophic vorticity at 700 mb. for the 30-day period May 28–June 27, 1951, in units of 10^{-5} sec.$^{-1}$. Areas of cyclonic vorticity in excess of 1×10^{-5} sec.$^{-1}$ are dotted and labeled "C" at the center; areas of anticyclonic vorticity less than 1×10^{-5} sec.$^{-1}$ are hatched and labeled "A" at the center.

2). There was some slight and rather spotty relief from thunderstorms during the month. This temporary relief did help to bring up some of the late-planted cotton which had been retarded several weeks in dry soil. Another area of deficient rainfall was in the Southeast which was under the influence of ridge conditions at sea level and anticyclonic relative vorticity at 700 mb. Between these two areas of below-normal rainfall, there was an area in Alabama of heavy precipitation. This was mainly the result of squall line showers in the warm air occurring early in the month.

Above-normal temperatures generally prevailed east of the Mississippi. This warm weather was associated with a relatively flat 700-mb. ridge extending from the Lower Lakes region to the eastern Gulf of Mexico. The greatest positive temperature departures were found in the Southeast where positive 700-mb. height anomalies were located. In the Northeast, however, there was some blocking action as indicated by above-normal heights centered just north of the Great Lakes and negative height departures off the South Atlantic Coast. This latitudinal superposition of positive over negative anomalies appeared to be the westward extension of a much more pronounced blocking pattern over the Atlantic. This blocking action is also indicated on the sea level pressure anomaly chart. Thus with stronger northeasterly flow than normal, portions of the Northeast experienced temperatures which were below the June normals.

The region off the East coast was a seat of frequent cyclonic development during June as northeasterly flow relative to normal along the coast brought cool polar air into contact with warmer air over the Gulf Stream. This favorable field for cyclonic development and activity was reflected in the curvature of the isopleths on the sea level and 700-mb. charts. The cyclones from the mean trough off the coast moved across the Atlantic along the nearly east-west sea level trough and the mean flow aloft. These storm tracks were well to the south of normal due to the strong blocking conditions in the North Atlantic, and some cyclones were even forced to recurve toward the west.

The pronounced trough-ridge pattern in the eastern Pacific resulted in a minimum of cyclonic activity in the eastern Pacific and on the west coast of the United States. Elsewhere in the United States and Canada storm activity appeared to be associated with below-normal heights and mean troughs at sea level. Further information about the storm tracks and centers of cyclonic activity can be obtained from the field of mean relative vorticity at 700 mb. (fig. 2). The centers of frequent storm activity coincide quite well with the centers of cyclonic vorticity, and the storms tended to move along the axis of cyclonic vorticity. The storms moving across the United States appeared to move freely in the westerly flow, whereas those along the central Canadian border showed a tendency toward motion in a more northerly direction around the anticyclonic vorticity center north of the Great Lakes.

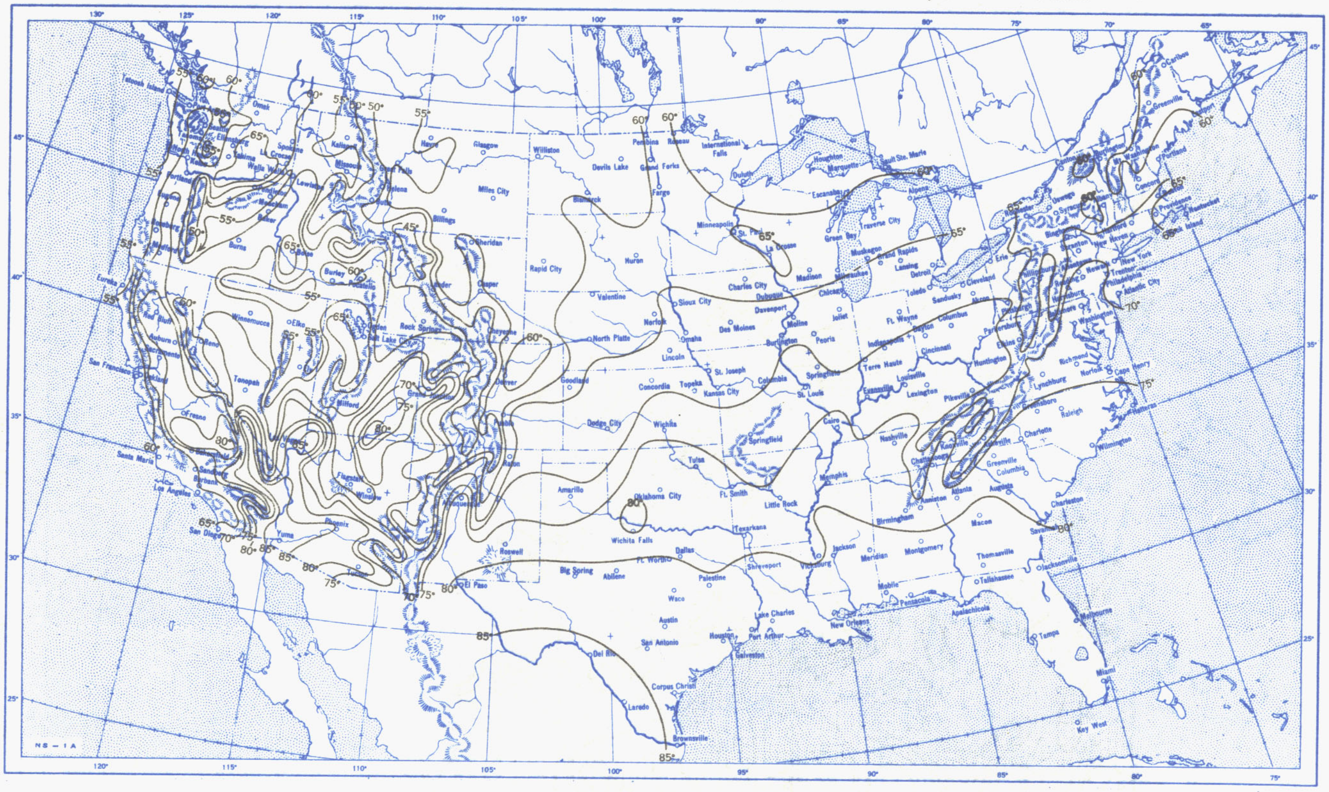
The anticyclones during the month of June (Chart IX) occurred most abundantly in the regions under the influence of anticyclonic vorticity at 700 mb. Usually the Highs tended to move along the axis of anticyclonic vorticity and appeared to intensify in the centers. This was very pronounced in the Eastern Pacific. The anticyclone moving northwestward toward the Gulf of Alaska on the 27th increased its central pressure by 7 mb. in 48 hours. However some of the Highs during June moved directly across regions of cyclonic vorticity, as for example those moving through Montana. These were cold and relatively shallow Highs which tended to weaken rather rapidly as they moved through these regions. The central pressure of one of these on June 25 was reduced by 8 mb. in 24 hours.

In retrospect, we might think of the circulation and contrasting weather of June as a dress rehearsal for the disastrous weather to come in July. Toward the end of June over the Great Plains, the interaction between warm moist air from the south and cold dry air from the north continued unabated and even intensified. As June ended, a flood was already under way in Kansas and Missouri. During July this flood was to become one of the most destructive in the Nation's history.

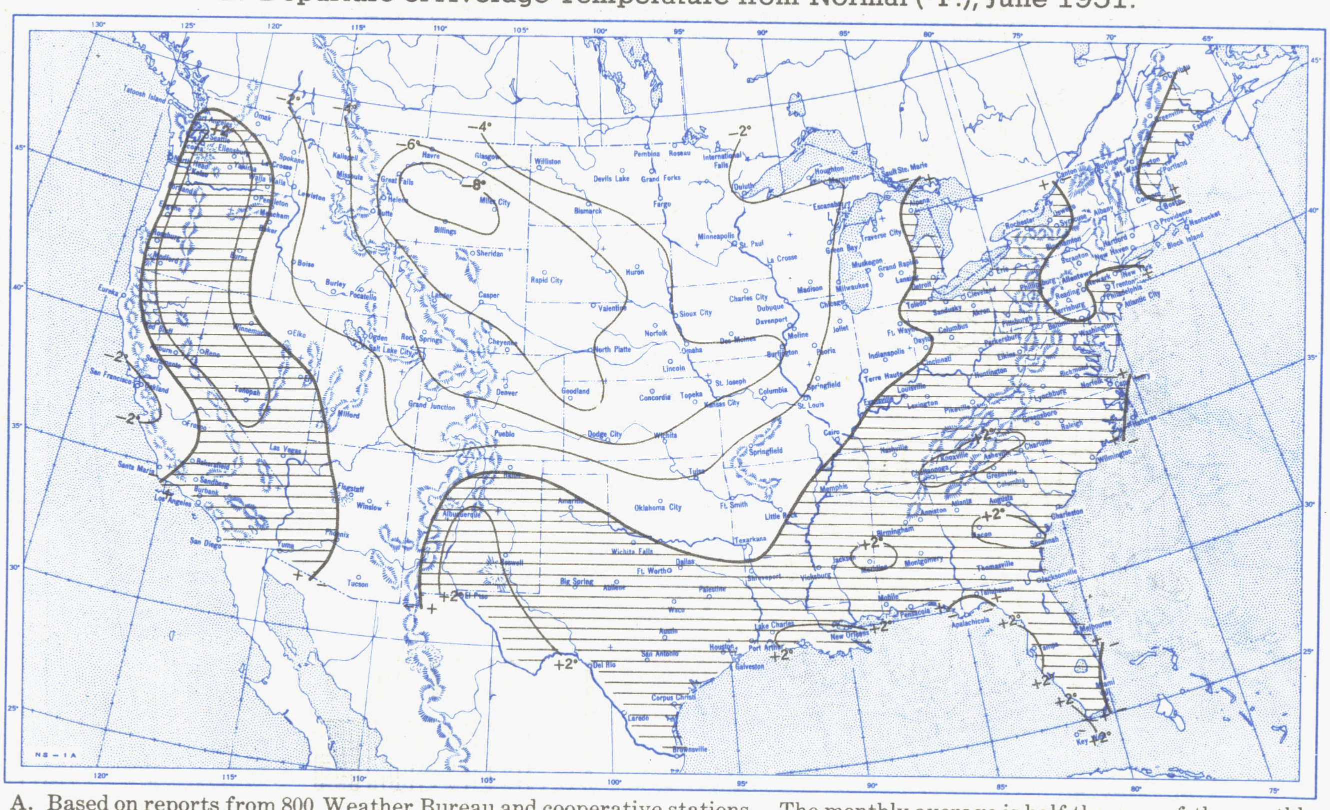
REFERENCES

1. J. A. Carr, "Snow and Record Cold in Wyoming and Montana, June 1–3, 1951," *Monthly Weather Review*, vol. 79, No. 6, June 1951, pp. 129–132.
2. L. H. Clem, "The Weather and Circulation of May 1951," *Monthly Weather Review*, vol. 79, No. 5, May 1951, pp. 96–99.

Chart I. A. Average Temperature (°F.) at Surface, June 1951.

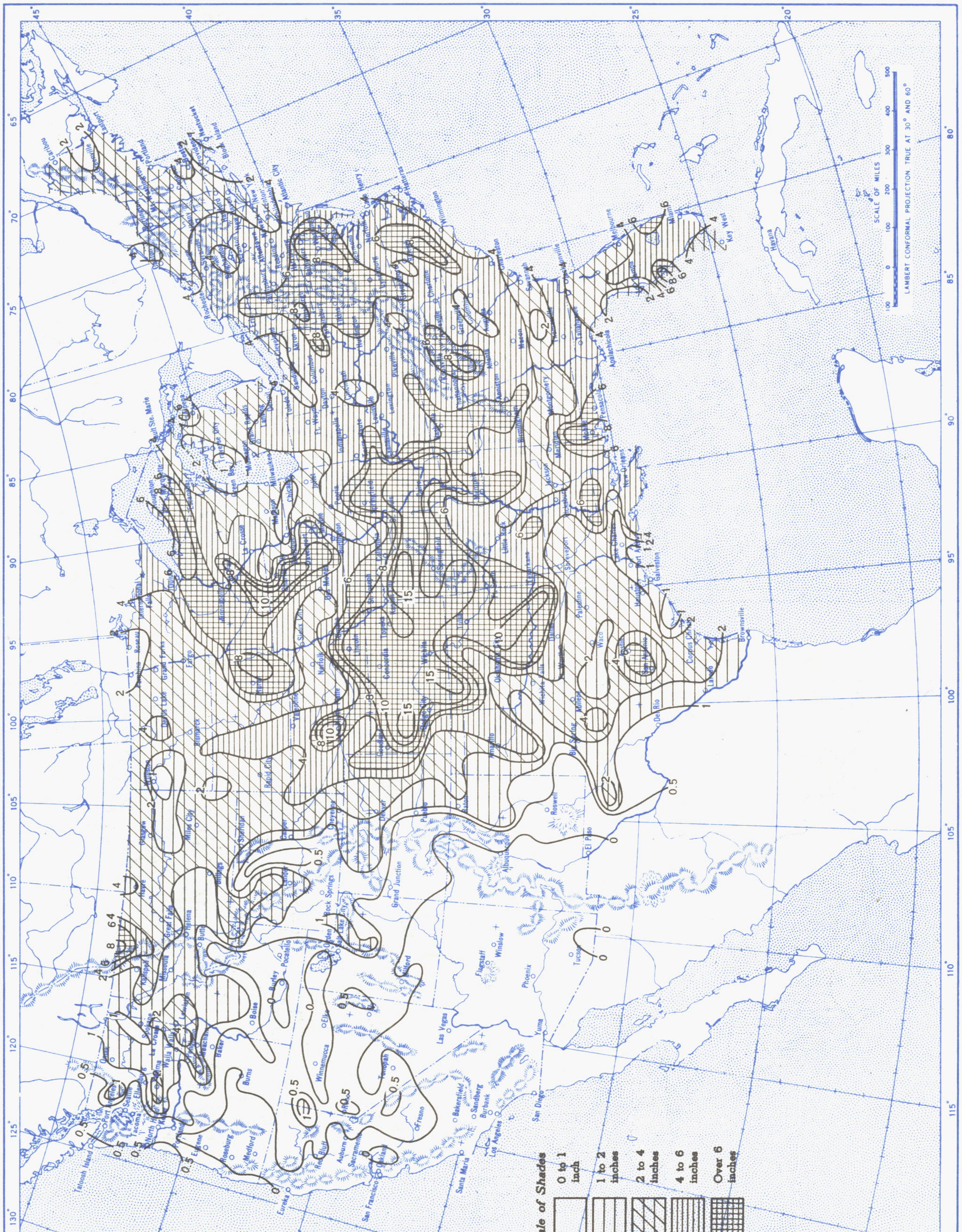


B. Departure of Average Temperature from Normal (°F.), June 1951.



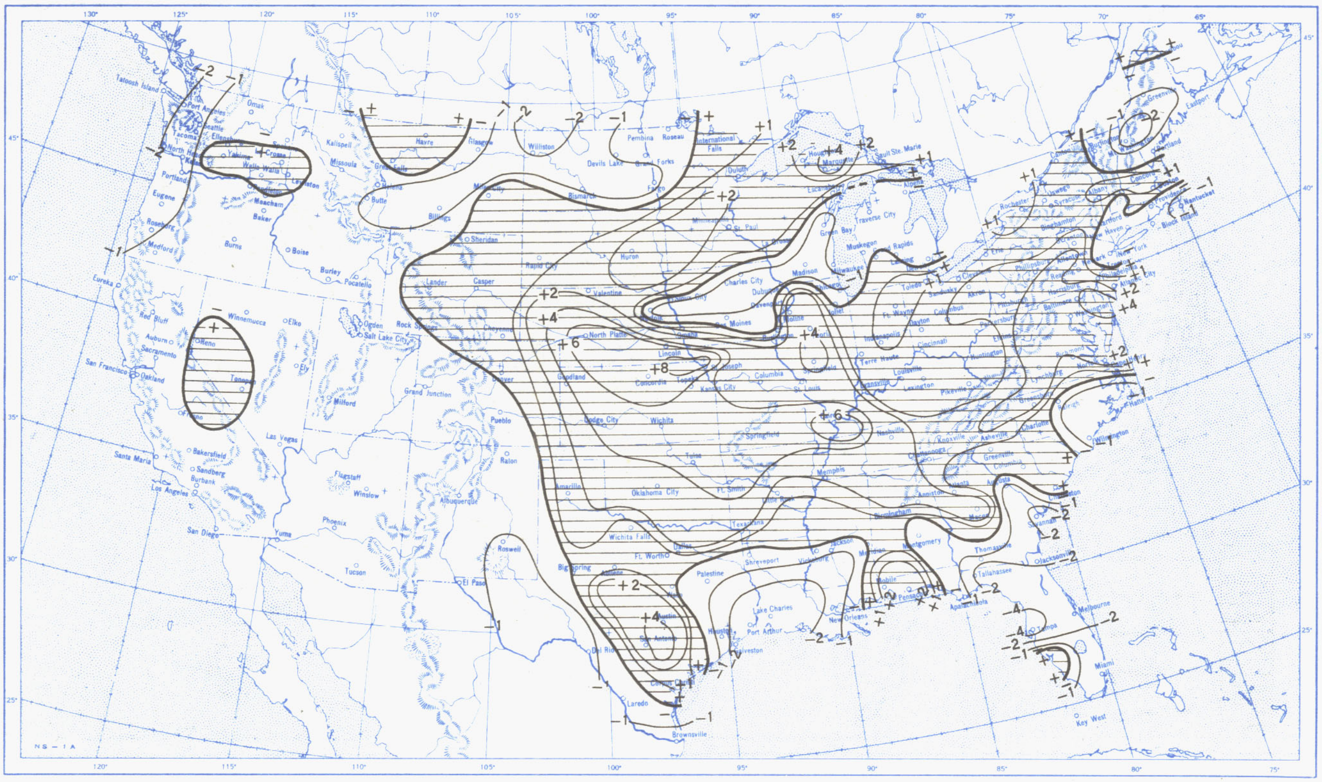
A. Based on reports from 800 Weather Bureau and cooperative stations. The monthly average is half the sum of the monthly average maximum and monthly average minimum, which are the average of the daily maxima and daily minima, respectively.
B. Normal average monthly temperatures are computed for Weather Bureau stations having at least 10 years of record.

Chart II. Total Precipitation (Inches), June 1951.

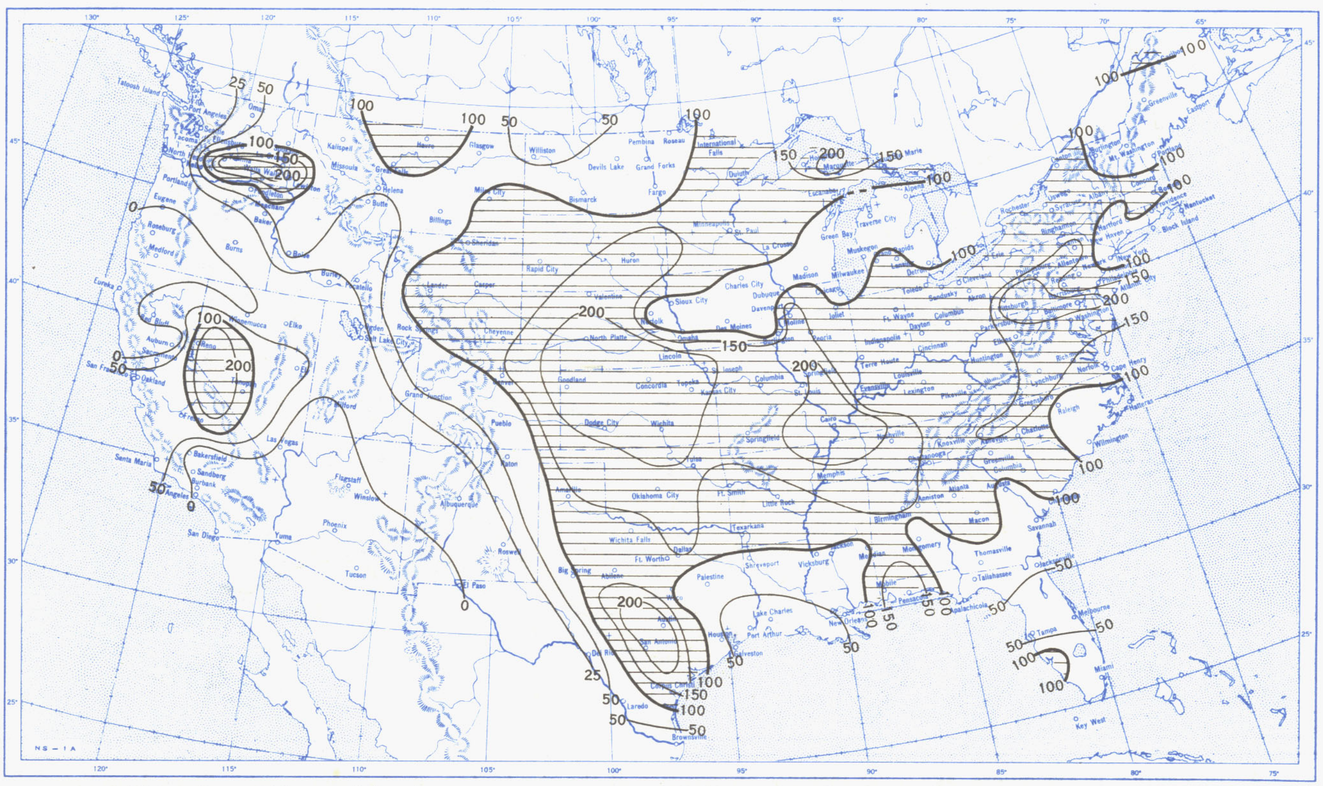


Based on daily precipitation records at 800 Weather Bureau and cooperative stations.

Chart III. A. Departure of Precipitation from Normal (Inches), June 1951.

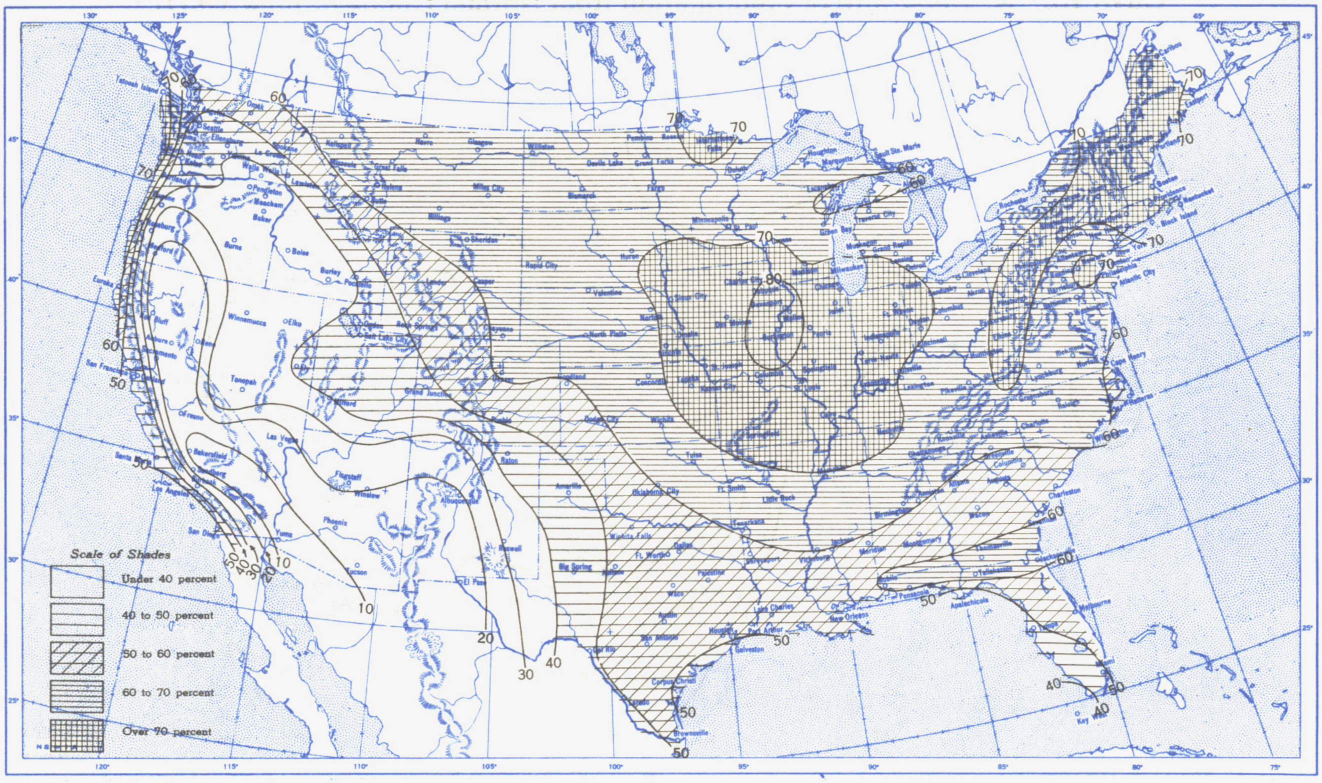


B. Percentage of Normal Precipitation, June 1951.

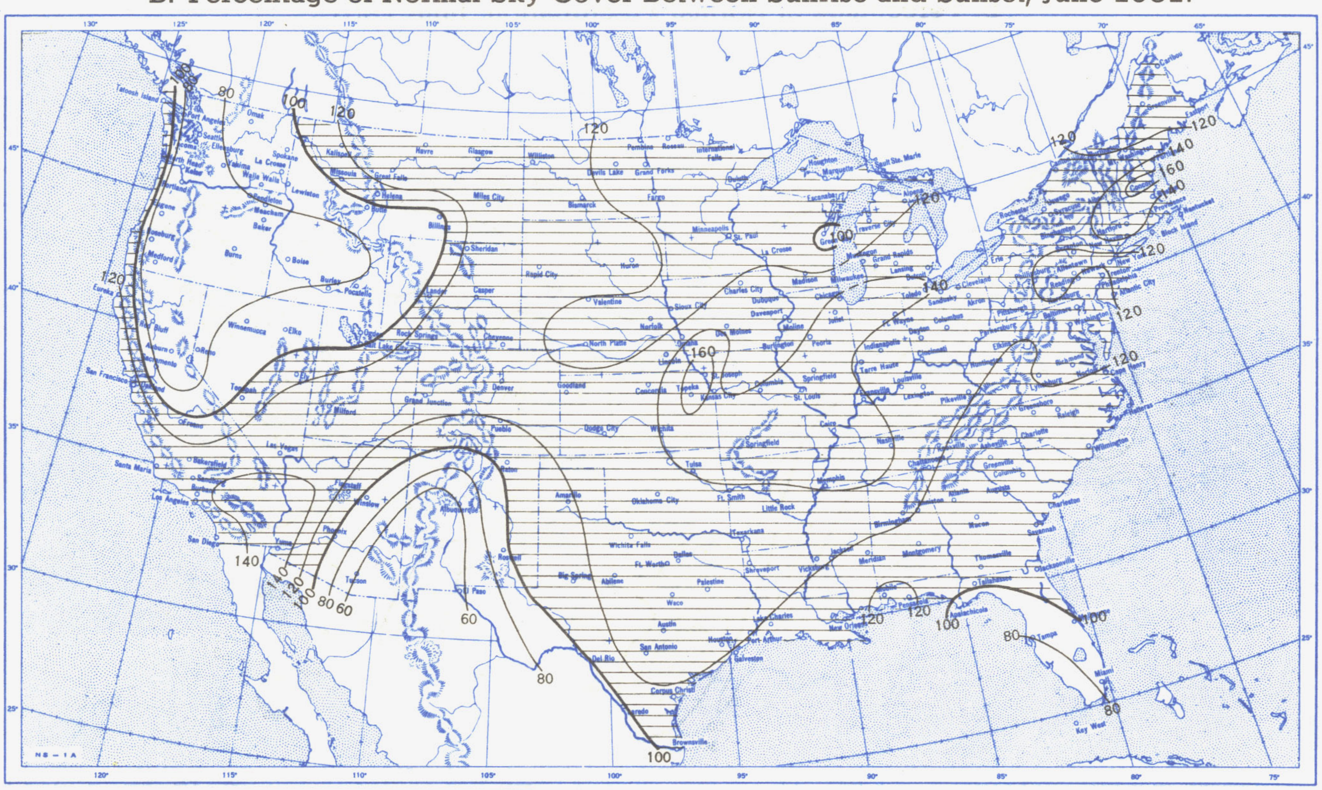


Normal monthly precipitation amounts are computed for stations having at least 10 years of record.

Chart VI. A. Percentage of Sky Cover Between Sunrise and Sunset, June 1951.

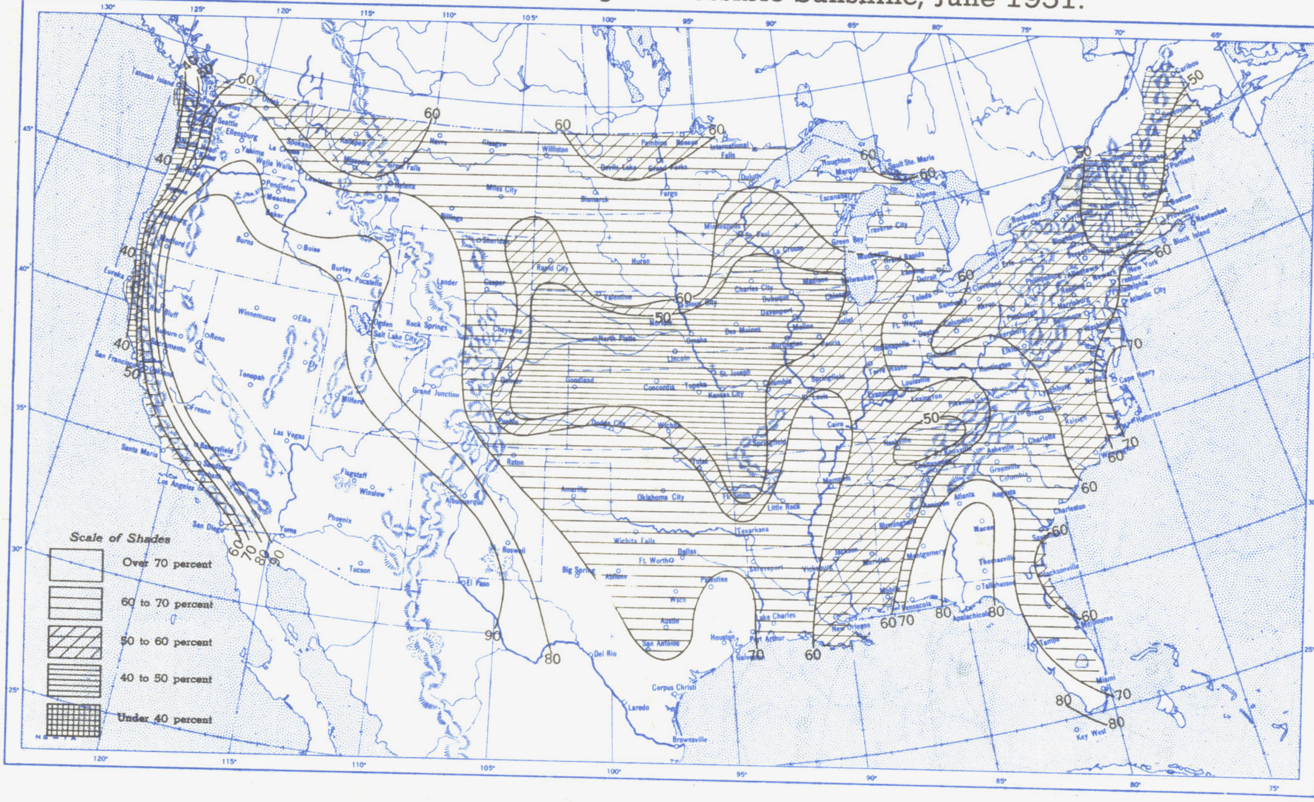


B. Percentage of Normal Sky Cover Between Sunrise and Sunset, June 1951.

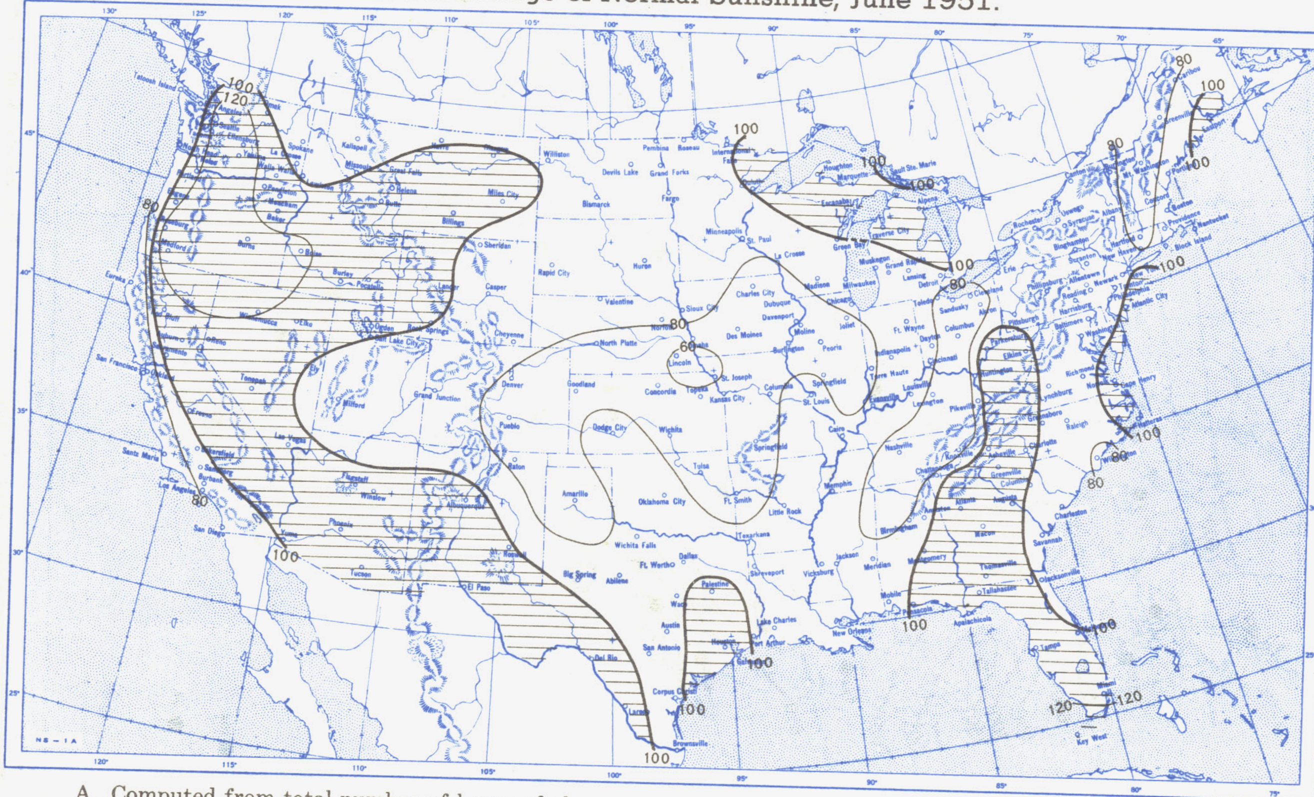


A. In addition to cloudiness, sky cover includes obscuration of the sky by fog, smoke, snow, etc. Chart based on visual observations made hourly at Weather Bureau stations and averaged over the month. B. Computations of normal amount of sky cover are made for stations having at least 10 years of record.

Chart VII. A. Percentage of Possible Sunshine, June 1951.



B. Percentage of Normal Sunshine, June 1951.



A. Computed from total number of hours of observed sunshine in relation to total number of possible hours of sunshine during month. B. Normals are computed for stations having at least 10 years of record.

Chart VIII. Average Daily Values of Solar Radiation, Direct + Diffuse, June 1951. Inset: Percentage of Normal Average Daily Solar Radiation, June 1951.

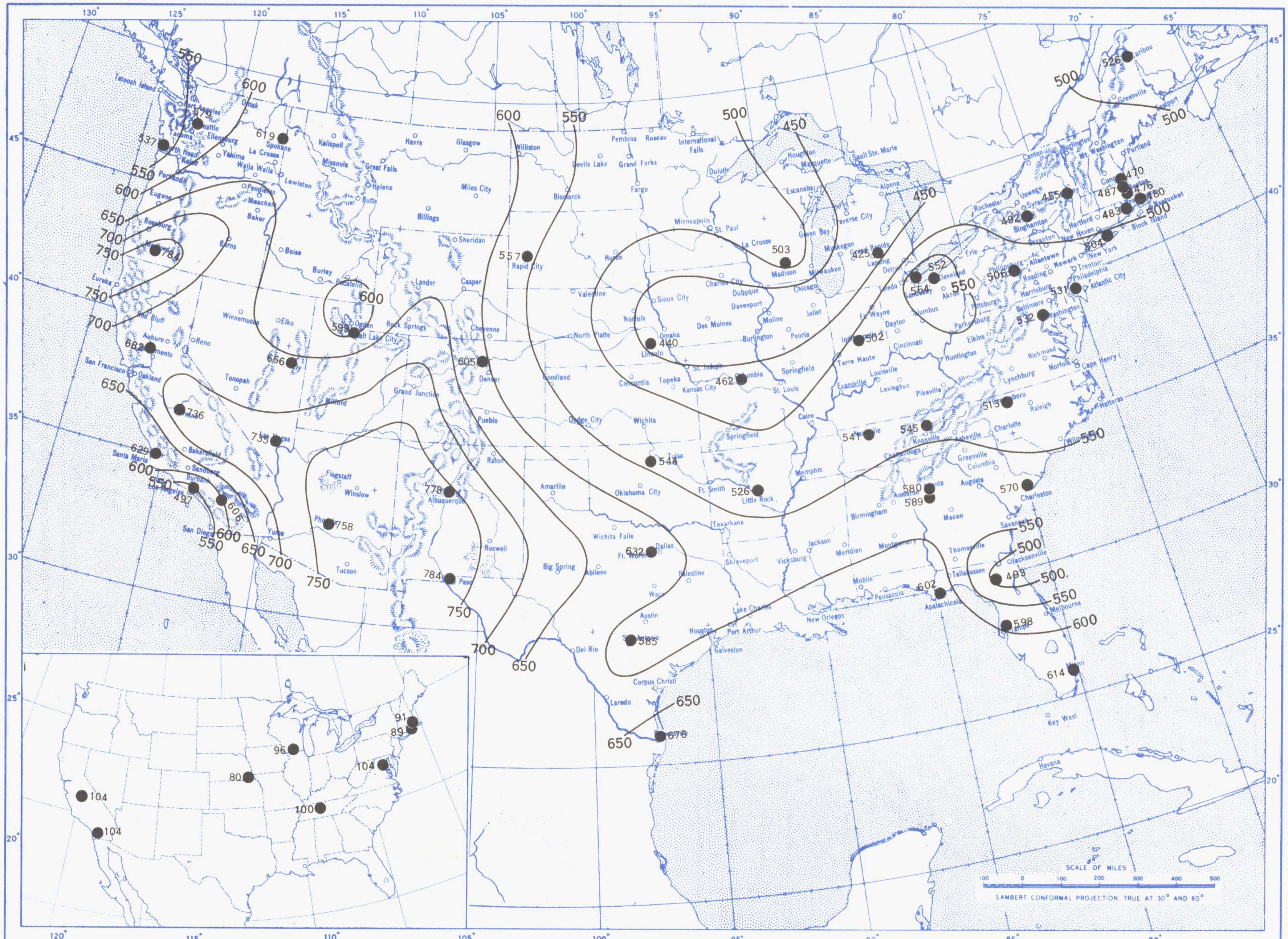
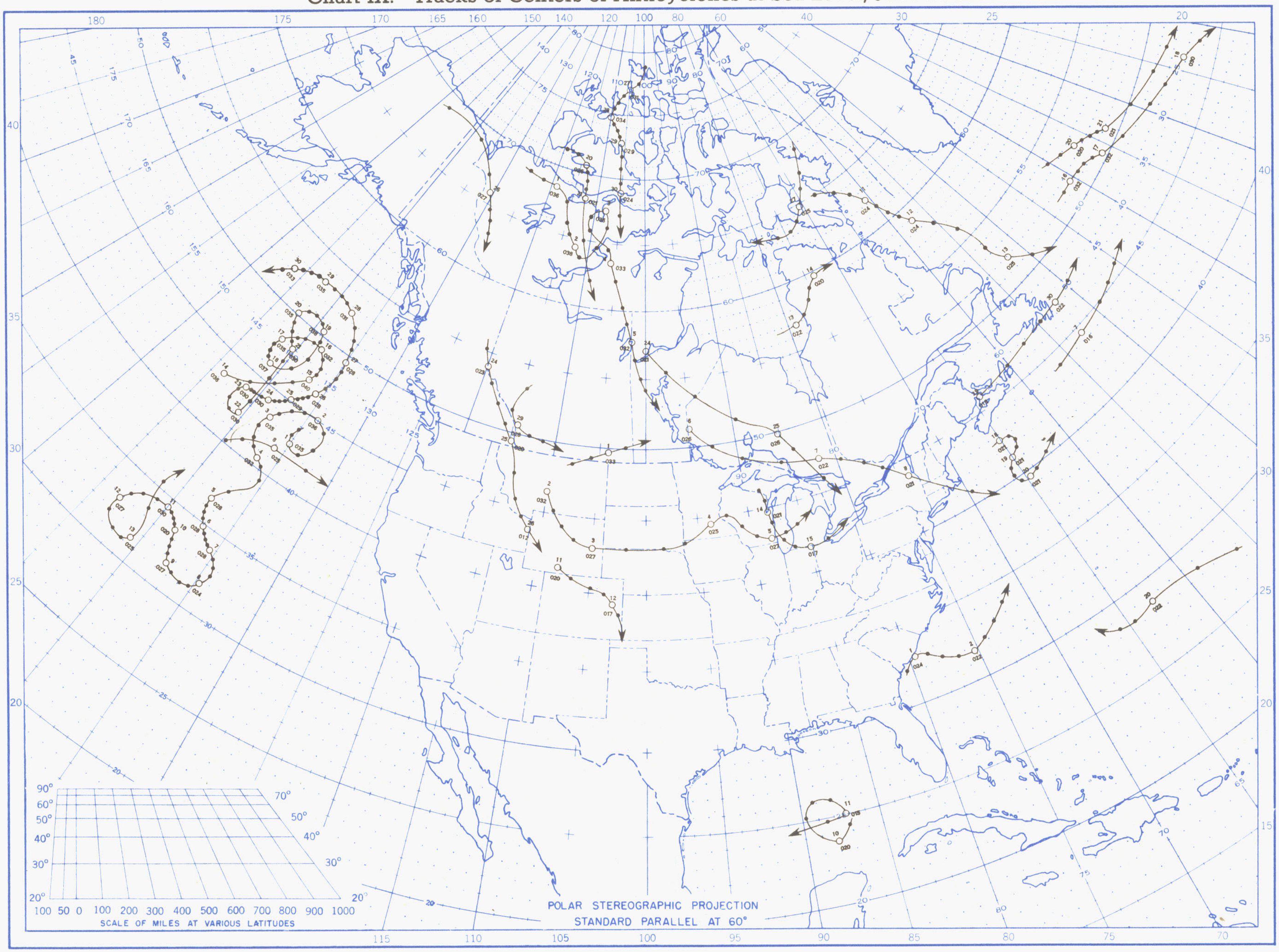


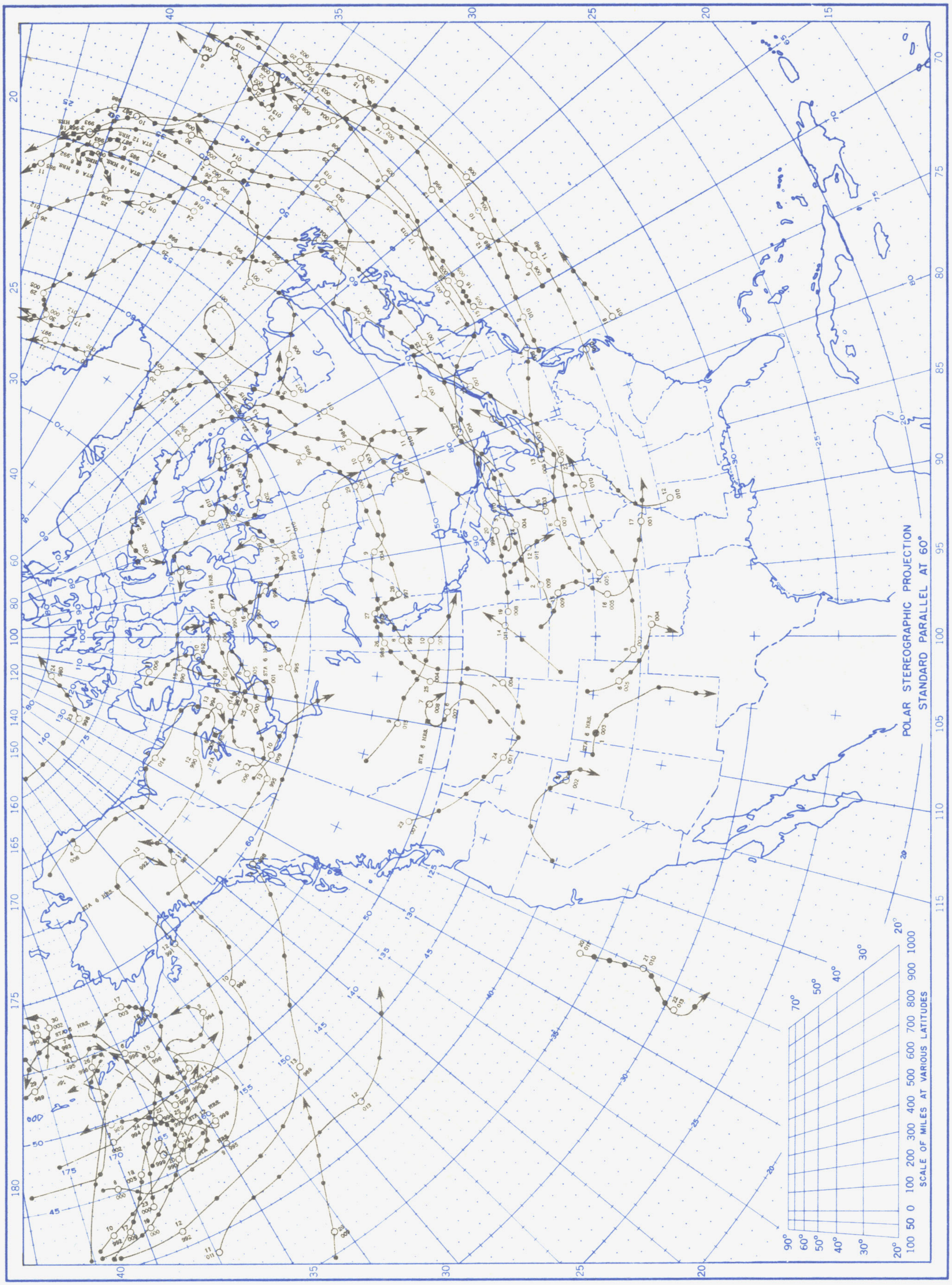
Chart shows mean daily solar radiation, direct + diffuse, received on a horizontal surface in langleys (1 langley = 1 gm. cal. cm. $^{-2}$). Basic data for isolines are shown on chart. Further estimates obtained from supplementary data for which limits of accuracy are wider than for those data shown. Normals are computed for stations having at least 9 years of record.

Chart IX. Tracks of Centers of Anticyclones at Sea Level, June 1951



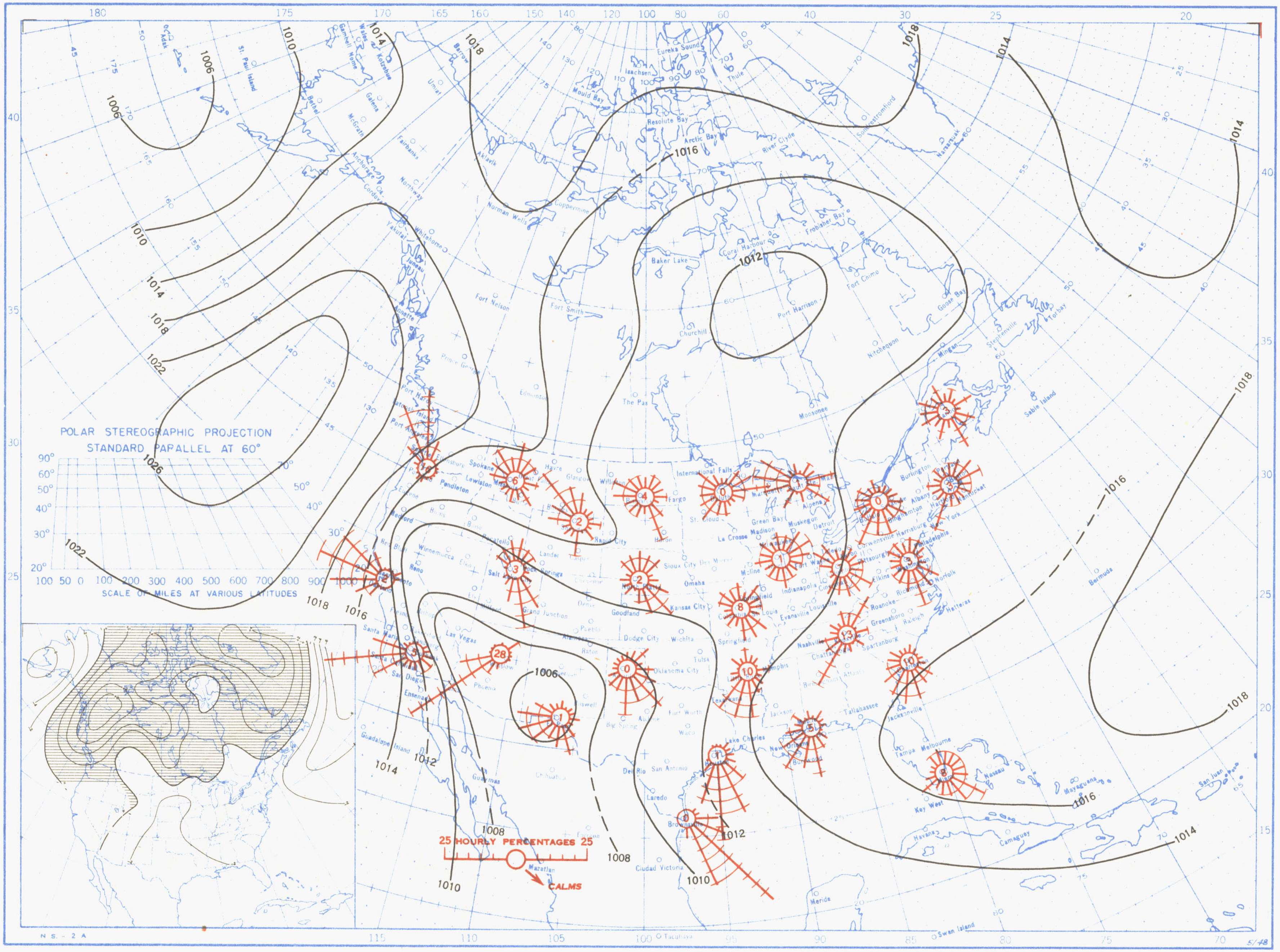
Circle indicates position of center at 7:30 a. m. E. S. T. Figure above circle indicates date, figure below, pressure to nearest millibar. Dots indicate intervening 6-hourly positions. Squares indicate position of stationary center for period shown. Dashed line in track indicates reformation at new position. Only those centers which could be identified for 24 hours or more are included.

Chart X. Tracks of Centers of Cyclones at Sea Level, June 1951.



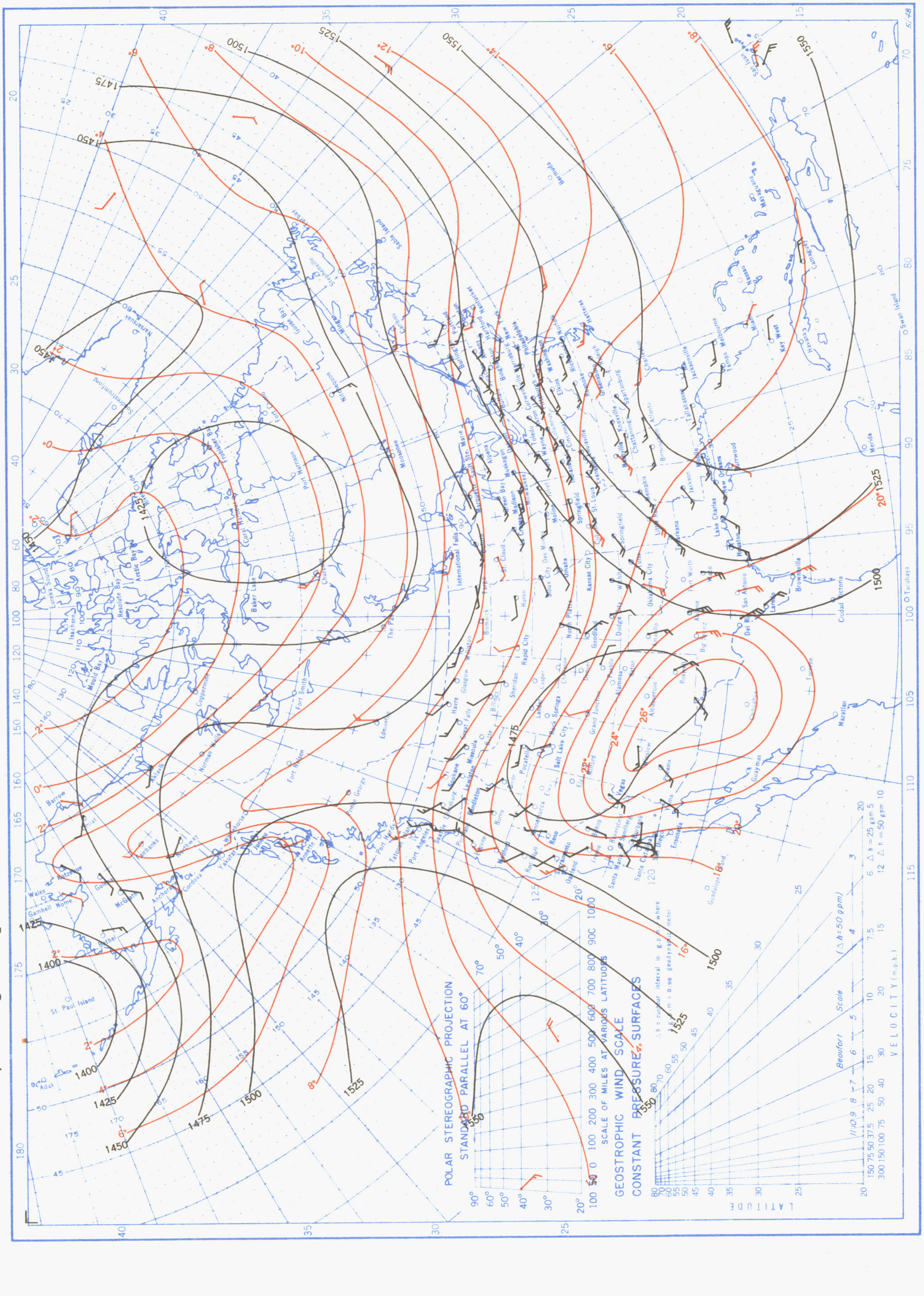
Circle indicates position of center at 7:30 a. m. E. S. T. See Chart IX for explanation of symbols.

Chart XI. Average Sea Level Pressure (mb.) and Surface Windroses, June 1951. Inset: Departure of Average Pressure (mb.) from Normal, June 1951.



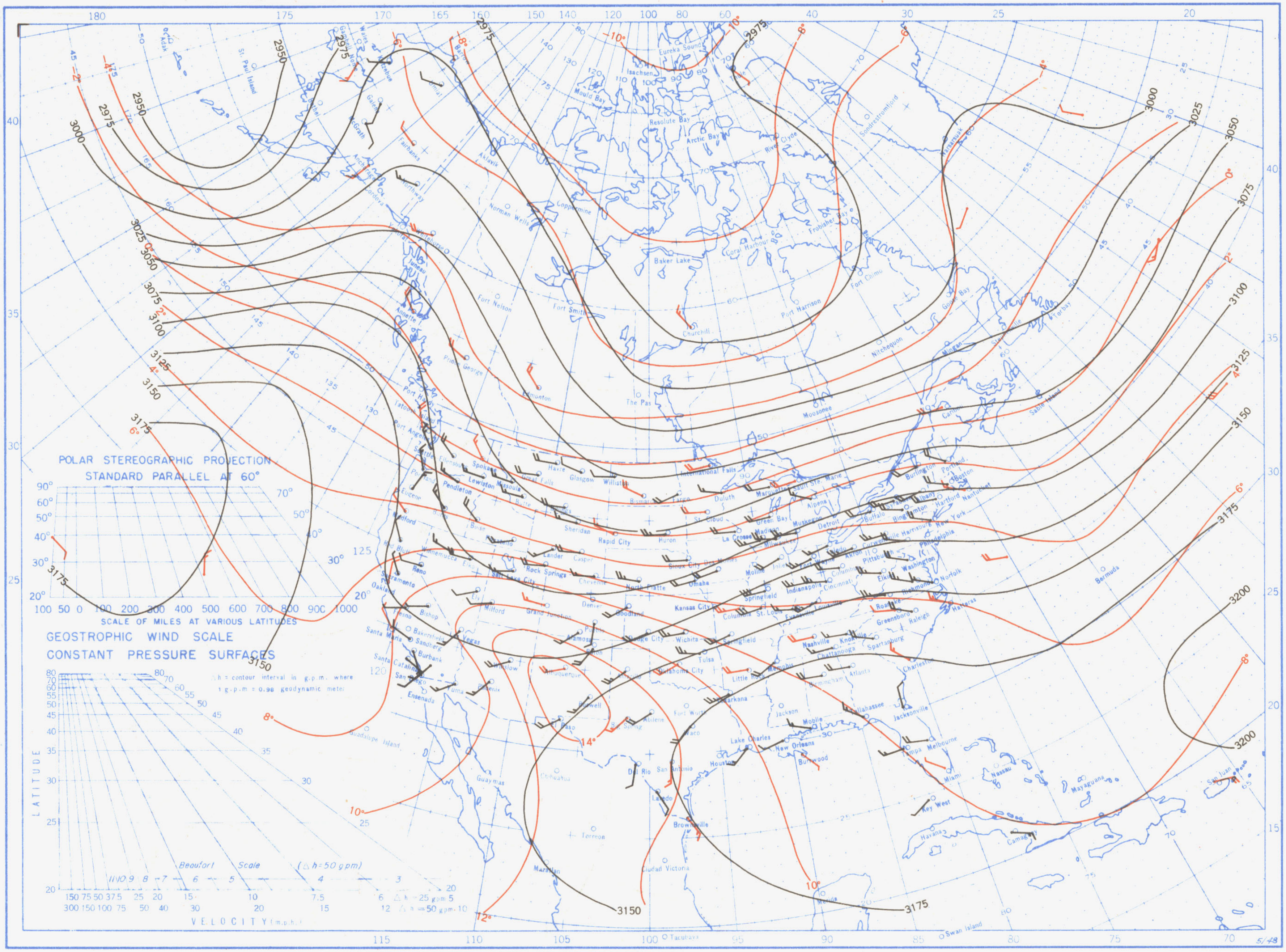
Average sea level pressures are obtained from the averages of the 7:30 a. m. and 7:30 p. m. E. S. T. readings. Windroses show percentage of time wind blew from 16 compass points or was calm during the month. Pressure normals are computed for stations having at least 10 years of record and for 10° intersections in a diamond grid from map readings for 20 years of the Historical Weather Maps, 1899–1939.

Chart XII. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 850-mb. Pressure Surface, Average Temperature in °C. at 850 mb., and Resultant Winds at 1500 Meters (m.s.l.), June 1951.



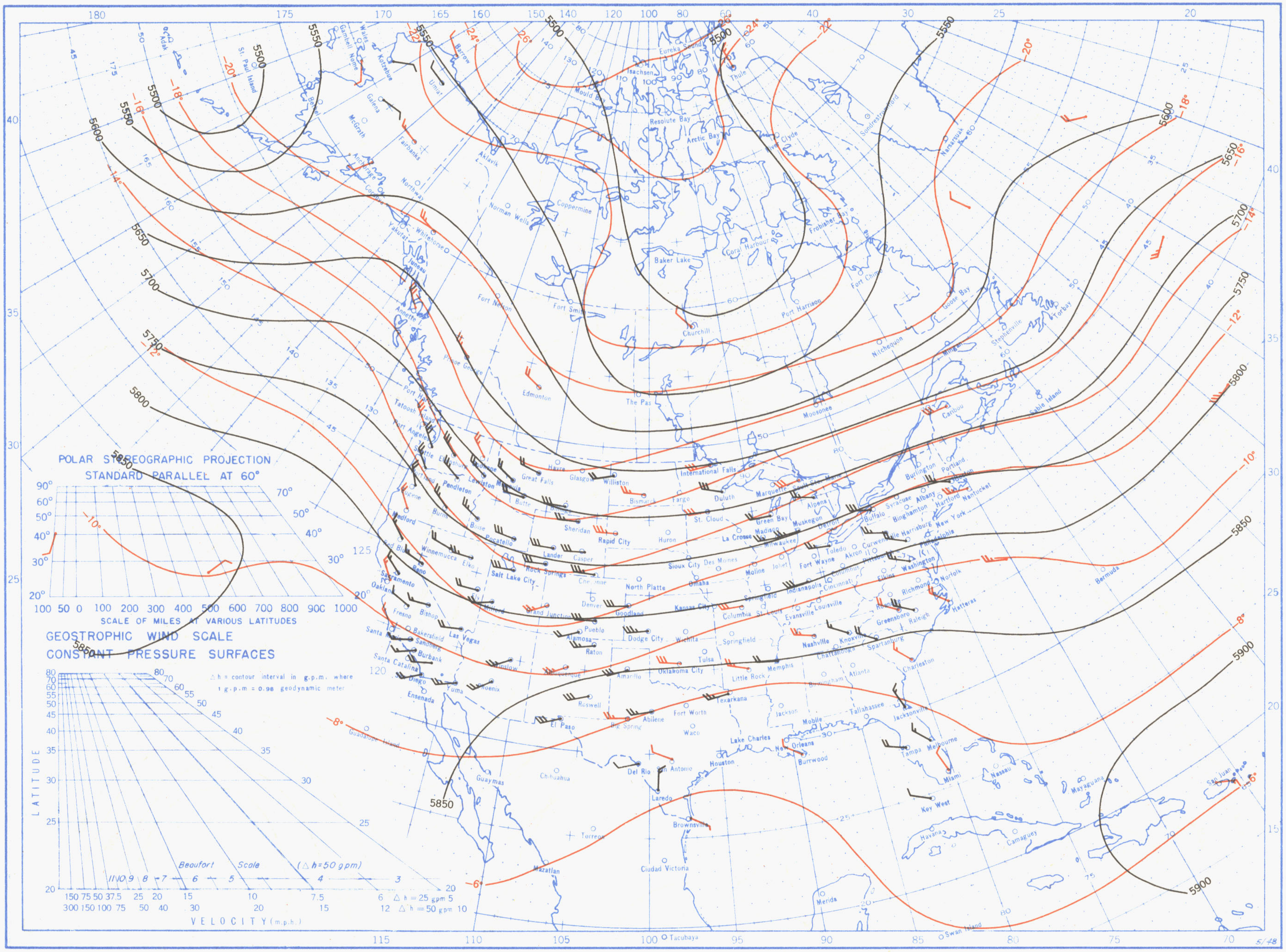
Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins taken at 0300 G. M. T.

Chart XIII. Average Dynamic Height in Geopotential Meters (1 g.p.m.. = 0.98 dynamic meters) of the 700-mb. Pressure Surface, Average Temperature in °C. at 700 mb., and Resultant Winds at 3000 Meters (m.s.l.), June 1951.



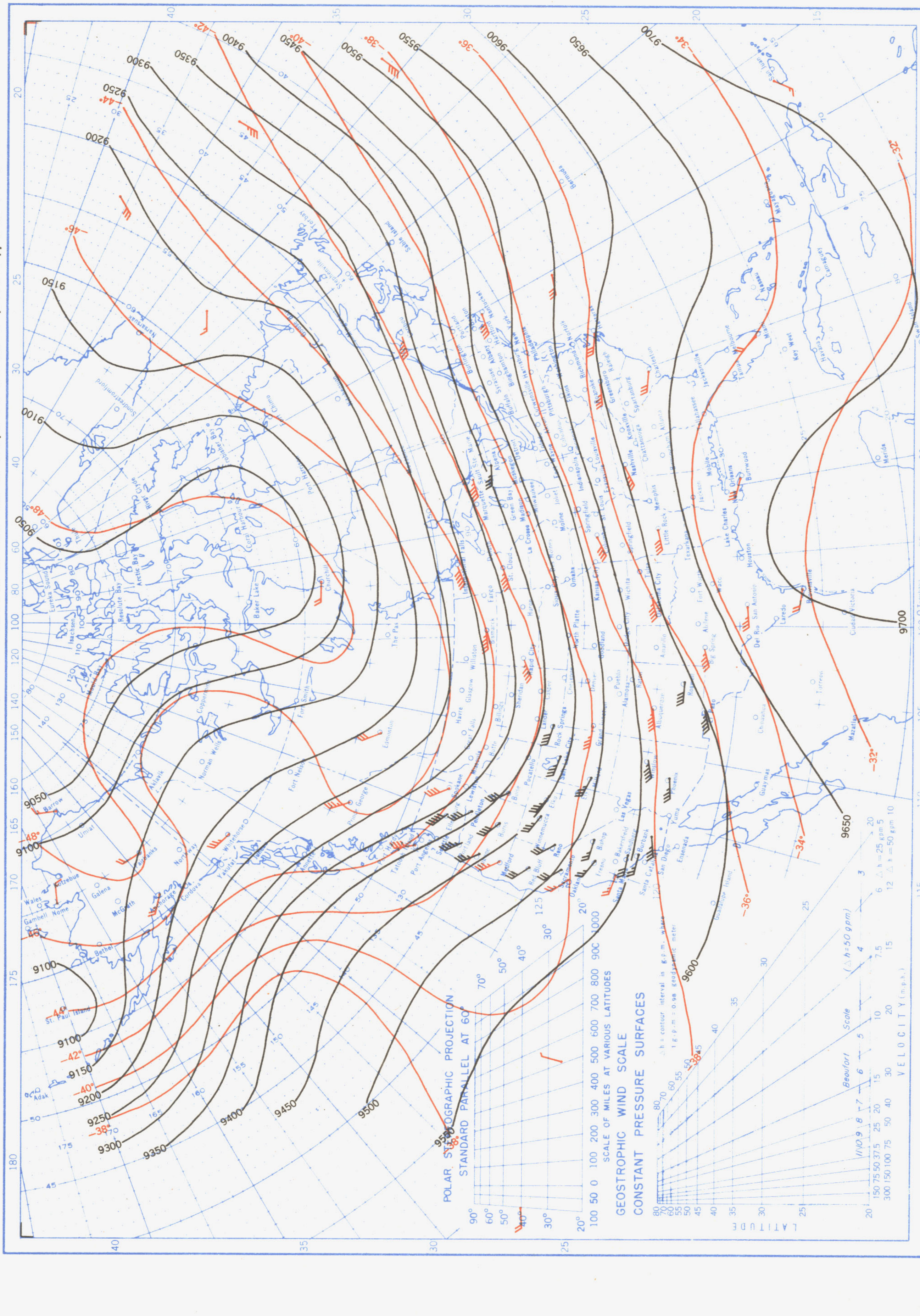
Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins taken at 0300 G. M. T.

Chart XIV. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 500-mb. Pressure Surface, Average Temperature in °C at 500 mb., and Resultant Winds at 5000 Meters (m.s.l.), June 1951.



Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins at 0300 G. M. T.

Chart XV. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 300-mb. Pressure Surface, Average Temperature in °C. at 300 mb., and Resultant Winds at 10,000 Meters (m.s.l.), June 1951.



Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins at 0300 G. M. T.